response, the Applicant has replaced all lower case figure references in the specification with upper case figure references to match the drawings submitted with the application.

In paragraph 3, under Claim Rejections, the Examiner has objected to claim 13. Original claim 13 has herein been deleted.

In paragraph 4, under Claim Rejections, the Examiner has rejected claims 17-20 under 35 U.S.C. § 112, first paragraph. Original claims 17-20 have been deleted.

In paragraph 7, under Claim Rejections, the Examiner has rejected claims 1-20 under 35 U.S.C. § 112, second paragraph, as being indefinite. The specific rejections are outlined in paragraph 8. The Applicant has modified claim 1 to remove the offending language and respectfully submits that the rejection based on these grounds has be traversed.

In paragraph 10, under Claim Rejections, the Examiner has rejected claims 1-2, 5-14 and 17-20 under 35 U.S.C. § 103(a) as being unpatentable over Applicant's admitted prior art (APA) in view of U.S. Patent 5,314,572 (Core, et al.). The Examiner has also rejected, in paragraph 11, claims 1-2, 4-12 and 5-16 under 35 U.S.C. § 103(a) as being unpatentable over the APA in view of U.S. Patent 5,083,857 (Hornbeck). Further, the Examiner rejected claim 3 under 35 U.S.C. § 103(a) as being unpatentable over the APA in view of Core, the APA in view of Hornbeck, or either in further view of U.S. Patent 5,493,177 (Muller, et al.).

In response to all three rejections under § 103(a), the Applicant has modified Claim 1 to add two limitations. The first limitation is that the etching rate differential between the structural material and the sacrificial material with respect to the non-liquid etchant used be high and, second, that a barrel etcher be used to apply the non-liquid etchant to the device.

The use of a barrel etcher is not known in the art for the purpose outlined in the Applicant's disclosure. In the device described in the disclosure, and with any device which is constructed in accordance with the Applicant's invention, a captured microstructure is constructed in the sealed cavity. Thereafter, holes are etched in the walls of the sealed cavity for purposes of introducing an etching agent to remove the sacrificial material which binds the microstructure to the substrate. A non-liquid etchant is utilized to eliminate the acknowledged problem of surface tension.

It is typical for the microstructures which would be built in accordance with this invention to be on the order of hundreds of microns in width. It is also undesirable to make multiple holes in the sealed cavity because, when such holes are sealed over, the material used as

a sealant constructs posts within the sealed cavity that could limit the size and mobility of the microstructure. Therefore, it is desirable to minimize the number of holes in the sealed cavity and to place the holes at or near the edges of the sealed cavity, as opposed to in the center.

Due to the nature of the charged plasma used as the etching agent, when introduced into the sealed cavity, it has a tendency to become electrostatically attracted to the surfaces of the microstructure and the substrate. Therefore, the areas containing sacrificial materials near the holes may be etched away rather quickly while areas inside of the cavity that are far from the etch holes, are etched extremely slowly if at all. Parts of the microstructure may be a distance of hundreds of microns away from the etch holes,. Because of the tendency of the etchant to adhere to the walls of the microstructure, very little of the etchant may find its way to the center of the sealed cavity.

For this reason alone, it is not obvious to use a non-liquid etchant within a sealed cavity. Further, to use a precision etching apparatus to perform this task makes the manufacture of devices non-economical because of the cost of the apparatus and the possible number of units that could be produced in a given time, due to the extremely long etching period required. None of the references cited by the Examiner solve this problem. Therefore, the Applicant has added the limitation of using a barrel etcher, which is typically not used for precision etching, to deliver the non-liquid etchant. The barrel etcher is considered a non-precision etching device and is often used for "clean-up" at the conclusion of an etching process. Further, the barrel etcher is capable of etching dozens of wafers, each of which may contain thousands of devices, at the same time. This requirement makes the process economical, even with the extended etching times required to release the microstructure, which can be on the order of hours or even tens of hours.

None of the references cited by the Examiner, either in combination with the ATA or with each other, teach the use of a barrel etcher to introduce a non-liquid plasma into a sealed cavity for purposes of releasing a MEMS microstructure from a substrate. As a result, the Applicant's submit that the Claims 1-5 and 21-23, as amended, are not obvious in view of the APA taken in combination with Core, Hornbeck, Mueller, et al. or any combination thereof.

Further, the Applicant's have added the limitation that the etch rate differential with respect to the non-liquid etchant of the structural material and the sacrificial material must be high. This is a result of the extremely l ng etch times in the barrel etcher when the sealed

cavities are exposed to the non-liquid etch agent. If the etch rate differential is not high enough, the non-liquid etch agent will attack the microstructure and the cavity walls as well as the sacrificial material during the extended time when the microstructure is exposed to the non-liquid etch agent. Therefore, only certain combinations of materials can be used as a sacrificial material in combination with a particular structural material. Aluminum and photoresist with an oxygen plasma etch agent is the preferred choice when practicing this invention, as the etch rate differential for these two materials are high with respect to an oxygen plasma etchant, however, other combinations may be acceptable.

CONCLUSION

The Applicant has addressed all of the informalities pointed out by the Examiner in the Office Action and further, has amended the claims and given reasons why the claims, as amended, are not obvious in view of the APA in combination with Core, Hornbeck or Mueller, et al. or any combination thereof. The Applicant therefore respectfully requests that the claim rejections under 35 U.S.C. § 103(a) be withdrawn and the pending claims, as amended, be allowed at the earliest possible time.

Respectfully submitted,

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ADDENDUM

(Marked Up Versions f Substituted Paragraphs in the Specification and Claims)

Specification:

Figures 1[a]A and [b]1B show a top view and a side cross-sectional view respectively of the silicon CMOS wafer used as the base of the MEMS micro-encapsulated structure.

Figures 2[a]A and [b]2B show a top view and a cross-sectional view respectively of the wafer of the Figure 1A with a sacrificial layer deposited thereon.

Figures 3[a]A and [b]3B show a top view and a cross-sectional view respectively of the wafer of Figures 2[a]A and [b]2B having a structural layer added thereon.

Figures 4[a]A and [b]4B show a top view and a cross-sectional view respectively of the wafer of Figures 3[a]A and [b]3B having a second sacrificial layer deposited thereon.

Figures 5[a]A and [b]5B show a top view and a cross-sectional view respectively of the wafer of Figures 4[a]A and [b]4B having a seal layer applied thereon.

Figures 6[a]A and [b]6B show a top view and a cross-sectional view respectively of the wafer of Figures 5[a]A and [b]5B having etch holes drawn therein.

Figures [7, 7a and 7c]7A, 7B and 7C show a top view, a cross-sectional view along line 7[b]B and a cross-sectional view along linc 7[c]C respectively of the wafer having the sacrificial layers removed by an enchant.

Figures 8[a]A and [b]8B show a top view and a cross-sectional view respectively of the wafer having a second seal layer applied thereon, thereby sealing the etch holes.

Figures 9[a]A and [b]9B show a top view and a cross-sectional view respectively of the second seal layer having been removed from the contact pad on the base wafer.

[Figure 1] Figures 1-9 illustrate[s] the sequence of steps comprising the fabrication of the proposed encapsulated integrated microstructure CMOS process. We start by obtaining or fabricating a silicon CMOS wafer 2 coated with a layer of silicon nitride 4 and having metal pads interfacing to the original CMOS integrated circuit 6, 8 and 10 present as shown. [Windows 7 and 9] Openings appear in the silicon nitride layer 4 to allow access to metal pads 6 and 8. In the preferred embodiment, the metal pads would be aluminum, but may alternatively be copper or any other conductive material.

To begin the fabrication process, a sacrificial layer 12 is deposited on top of the passivation layer of the standard CMOS wafer 2, which in this case is silicon nitride layer 4. The MEMS device fabrication steps are all performed at low temperature on top of the complete CMOS wafer 2, leaving the circuitry therein undisturbed. Cuts in the passivation layer 4 are left during the CMOS IC design and sacrificial layer 12 is removed over these cuts if access to the metal contacts is desired. The exposed metal contacts 6 and 8 are then used to make connections between the MEMS microstructure and the CMOS circuitry in silicon CMOS wafer 2 below. This is illustrated in Figure 2[a]A.

The deposition of the MEMS layer is shown in Fig. 3[a]A and in [top view] cross section in Fig 3[b]B. MEMS microstructure 14 is deposited by methods known by those with ordinary skill in the art and the undesirable portions are etched away, thereby leaving the desired shape of the microstructure behind[ ]. The top view of Figure 3[b]B clearly shows the shape of the microstructure as being a paddle having a long thin beam attached to an anchor point, which in this case is metal contact 8.

Next, as shown in Fig. 4[a]A, and in [top view]cross section in Fig. 4[b]B, a second sacrificial layer 16 is deposited over the microstructure. It can be seen from the top view that portions of the top sacrificial layer 16 will come into contact with portions of the bottom sacrificial layer 12, in particular, those areas near the edges of the paddle-shaped main body of

the microstructure and those areas on either side of the thin connecting beam p rtion of the microstructure.

The preferred material for sacrificial layers 12 and 14 is photoresist. Photoresist is chosen for this reason because it can be etched with an oxygen plasma gas, which is not destructive of aluminum microstructure 14, silicon nitride passivation layer 4 or seal layer 18. Figures 4[a]A and 4[b]B show the deposition of second sacrificial layer 16.

Figures 5[a shows]A and 5B show the deposition of seal layer 18. This layer may be composed of an insulator or a conductor, depending on the desired electrical operation of the microstructure. Additionally, the seal layer must have a low enough residual stress and must be thick enough that the membrane created by the seal layer 18 will not buckle after the sacrificial layers 12 and 16 have been removed. In the preferred embodiment, seal layer 18 is the same metal as was chosen for the microstructure layer 14, but in alternate embodiments may be made of any material resistant to the etchant chosen. In the event an insulating material is chosen for seal layer 18, it may be patterned and removed to give access to the non-MEMS parts of the integrated circuit, such as bond pads 6 and 8. If seal layer 18 is a conductor, it may be contacting one or both of bond pads 6 or 8.

Next, one or more etchant access holes 20, shown in Fig. 6[a]A and 6[b]B are etched into seal layer 18 such that communication can be established with sacrificial layers 12 and 16. This etch is done by any means well known to anyone of ordinary skill in the art. Preferably etch holes 20 will be as far away as possible from the actual MEMS microstructure. Next, as shown in Figs. 7[a]A, 7[b]B and 7[c]C, the etchant is introduced into holes 20 and sacrificial layers 12 and 16 are etched away, leaving void 22. Figure 7[b]B shows a cross-sectional view of the device through the center, while Figure 7[c]C shows a cross-sectional view through one of the etchant access holes. A dry plasma etchant is used to avoid problems created by the surface tension of a wet etchant. In the preferred embodiment, the etchant is oxygen plasma. Oxygen plasma was chosen because it is highly selective with respect t the etching sacrificial layers 12 and 14, which may be ph toresist or other organic polymers, while having an extremely low etching rate for a wide variety of metals and insulators.

The final step, shown in Fig. 8[a]<u>A</u>, is the application of a second seal layer 26 to seal etch holes 20. In the preferred embodiment, seal layer 26 is the same metal as seal layer 18 and MEMS microstructure 14. As shown in Fig. 9, if the second seal layer is not a conductor then it may be etched away using well known methods from the area over contact pad 6, or it may be left in electrical contact with compact pad 6.[. final] <u>Final</u> seal layer 26 may be etched away from contact pad 6, or, if seal layer 26 is composed of a conductor, may be left in place.

<u>Claims</u>:

1. (Amended) A method of fabricating a <u>microstructure in a</u> sealed cavity [for containing a microstructure] comprising the steps of :

providing a substrate;

<u>forming a microstructure composed of a structural material on said substrate in a sealed cavity, said microstructure being secured to said substrate at one or more points by a sacrificial material;</u>

[depositing one or more sacrificial layers on said substrate;

depositing a first seal layer on top of said one of more sacrificial layers;]

forming one or more holes in said <u>sealed cavity;</u> [first seal layer, said holes communicating with said one or more sacrificial layers;]

introducing [an] <u>a non-liquid</u> etchant into said <u>sealed cavity through said</u> one or more <u>holes using a barrel etcher, said etchant having a high etch rate with respect to said sacrificial material and a low etch rate with respect to said structural material, such that said sacrificial material is removed; and</u> [such that said one or more sacrificial layers are etched away by said etchant;

depositing a second seal layer on top of said first seal layer, said second seal layer] sealing said one or more holes <u>in said sealed cavity.</u> [in said first seal layer;] [wherein said etchant used to remove the last of said sacrificial layers is a non-liquid material.]

2. (Amended) The method f claim 1 further comprising the step of choosing said etchant to etch said sacrificial [layers] <u>material</u> without substantially etching said substrate or said [first seal

layer.] <u>microstructure.</u>

3. (Unchanged)

4. (Amended) The method of claim 2 wherein said etchant is oxygen plasma, [and] said [one or more] sacrificial <u>material</u> [layers are] <u>is</u> [composed of] photoresist[.] <u>and wherein said structural material is aluminum.</u>

[5. The method of claim 1 further comprising the step of forming a microstructure in said cavity.]

[6. The method of claim 5 wherein said step of forming a microstructure in said cavity comprises the steps of:

depositing one or more layers of structural material between said one or more sacrificial layers;

shaping said structural material to the shape of the desired microstructure; and

removing said one or more sacrificial layers using a non-liquid etchant.]

[7. The method of claim 6 wherein said step of shaping comprises the steps of:

depositing a layer of photoresist over said layer of structural material;

etching away said structural material leaving the desired shape; and

removing any remaining photoresist material.]

[8. The method of claim 6 wherein said structural material is resistant to said etchant.]

[9. The method of claim 8 wherein said structural material is aluminum and wherein said etchant is oxygen plasma.]

[10. The method of claim 9 wherein said sacrificial layers are composed of an organic polymer.]

[11. The method of claim 10 wherein said organic polymer is photoresist.]

[12. The method of claim 7 wherein said microstructure is released when all surrounding sacrificial layers are etched away.]

[13. The method of claim 7 wherein said sacrificial layers are made of different materials and wherein a wet etchant may be used to remove all but the last or said sacrificial layers holding said microstructure.]

[14. The method of claim 13 wherein said last sacrificial layer holding said microstructure is removed using said non-liquid etchant.]

[15. The method of claim 6 wherein each all of said sacrificial layers are composed of the same material.]

[16. The method of claim 15 wherein said etchant is oxygen plasma and wherein each of said one or more sacrificial layers are composed of photoresist.]

[17. The method of claim 15 wherein said sacrificial layers may be composed of different materials.]

[18. The method of claim 17 wherein at least one of said sacrificial layers is composed of photoresist.]

[19. The method of claim 18 wherein said sacrificial layers composed of photoresist are removed last.]

[20. The method of claim 19 wherein said sacrificial layers composed of photoresist are removed using an oxygen plasma etchant.]